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# U.S. Adults with Agricultural Experience Report More Genetic Engineering Familiarity than Those Without

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**Abstract**

*Researchers and pollsters still debate the acceptance of genetic engineering technology among U.S. adults, and continue to assess their knowledge as part of this research. While decision-making may not rely entirely on knowledge, querying opinions and perceptions relies on public understanding of genetic engineering terms. Experience with agriculture may increase familiarity with genetic engineering terms. We conducted a national survey of 429 United States adults through Qualtrics and found two-thirds lack any formal, nonformal, or informal agriculture experience. More than half of participants knew "a little" or less for 13 of the 17 terms presented, especially those directly related to genetic engineering or breeding technology for food, such as "genetically modified organism" and "crossbred organism." Consumers with agricultural experience reported more term familiarity for genetics and genetic engineering than those without experience. More than half also felt they did not know the difference between traditional selective breeding, DNA-directed breeding, and genetic engineering, but they still felt both human health and environmental risks should be considered before creating new animal or plant varieties. We must consider the lack of familiarity of genetic related terms and experience in agriculture when researching or creating educational programming around genetic engineering for food.*

**Keywords:** genetic engineering; public understanding of science; agricultural experience; genetically modified organism; term familiarity

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## Introduction

Consumers are more aware of and interested in the agricultural industry as agriculturalists meet new demands of feeding a growing population (Anderson, Ruth, & Rumble, 2014). At the same time, only 2% of Americans live on farms and directly experience agriculture, a rate much lower than in the mid-20th century (Environmental Protection Agency, 2013). By another measure, if involvement in high school agriculture is the standard for agricultural experience (Duncan, Carter, Fuhrman, & Rucker, 2015; Dyer, Breja, & Wittler, 2002; Esters, 2007), then only 6% of younger adults in the U.S. are likely to have any direct agricultural experience. Estimates suggest at most one million high school students are involved in FFA (National FFA Organization, 2013) out of over 15 million public high school students in the U.S. (National Center for Education Statistics, n.d.).

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Agriculturalists and scientists work together to determine agricultural needs and potential scientific solutions, pairing the scientific and agricultural communities and industries. Overall, science as a field enjoys broad support from adults in the United States (Pew Research Center, 2015), while support for agriculture may be much lower (Lundy, Ruth, Telg, & Irani, 2006; Pilger, 2015; Wachenheim & Rathge, 2000). Americans may also see agriculture and science differently than scientists do, as more separate than intrinsically linked (Stofer & Newberry III, 2017). Particularly for agribiotechnology, Americans may not trust the underlying science as much as they do in other domains (Blaine, Kamaldeen, & Powell, 2002; McHughen, 2007; Moon & Balasubramanian, 2004).

One such agribiotechnology which scientists support (Chassy, 2007) but the public may not is genetic modification and genetic engineering (GE). Such technology allows for the manipulation of genes to produce a desired trait, creating improvements in growth rate, disease and insect resistance, and nutritional value. Although genetic engineering has been around for several decades, national polls and evaluation studies of United States adults indicate many may still be unsure of the risks and benefits of genetic engineering specifically for food production and may not accept the use of this agricultural technology (Evans & Ballen, 2016; Hallman, Cuite, & Morin, 2013; Traill et al., 2006). Indeed U.S. adults may be far apart from scientific consensus on the issue of safety for human consumption (Pew Research Center, 2015). However, these national studies also treat GE technology as a single issue, rather than a set of related cases for individual crops and the improvements targeted. For example, perceptions of risks and benefits of GE to save a rapidly declining citrus crop in the exigent case may be different from a discussion of fortifying rice with beta-carotene for better nutrition in under-resourced areas.

However, others suggest that genetically engineered foods are not controversial in the United States, both because the aforementioned surveys are invalid and because consumers buy GE foods despite their poll answers (Kahan, 2015). None of these non-peer-reviewed data sources actually considers whether consumers know what GE involves for food, nor specifically examine human health versus environmental risk perception (Stofer & Schiebel, 2017). As people may prefer phenomena with which they are familiar (Zajonc, 2001), lack of exposure to these terms may be another reason people indicate low acceptance of a technology when asked. If research participants lack familiarity with specialized terminology used to determine opinions, researchers will not be able to determine consumers' true feelings toward the technology (Sturgis & Allum, 2004; Sturgis, Brunton-Smith, & Fife-Schaw, 2010; Wynne, 2006).

We have few recent, national peer-reviewed studies suggesting consumers actually know what genetic engineering technology for food involves, the differences in human health and environmental risks, let alone whether they support its use in general or specific cases (Stofer & Schiebel, 2017). Indeed, a single national evaluation report (Hallman et al., 2013) and one peer-reviewed study (Abrams, McBride, Hooker, Cappella, & Koehly, 2015) suggest U.S. adults may not be completely aware of or clear on the meaning of genetic engineering technology, and thus they are unable to validly respond to research soliciting opinions on whether to support the use of the technology. Related research on consumer opinions of another emerging technology, nanotechnology, suggests that once consumers do become more informed, they may become polarized on the issues of risk based on cultural associations, rather than knowledge (Kahan, Braman, Slovic, Gastil, & Cohen, 2009). Current research in agricultural education on biotechnology attitudes (Ruth, Rumble, Gay, & Rodriguez, 2016; Wingenbach, Rutherford, & Dunsford, 2003) may focus on undergraduates and often undergraduates at land-grant institutions, which may not be representative of the U.S. population as a whole.

Genetic engineering brings a new list of associated vocabulary and jargon that researchers have used without definitions in surveys and focus groups when studying GE technology and food (Stofer & Schiebel, 2017). Determining the public's awareness of terms frequently used with the technology and determining their experience in agriculture can help GE researchers and marketers understand consumers' concerns about the technology especially as it relates to food production. Understanding the public's broader literacy about genetics also interests the American Association for Agricultural Education (AAAE). Priority 1 of the National Research Agenda focuses on public and policy maker understanding of agriculture and natural resources (Enns, Martin, & Spielmaker, 2016). Combining understanding of the public's term familiarity, actual perceptions of genetic engineering when research participants understand the technology and terms, and experience in agriculture can guide researchers and practitioners in designing information and outreach programming aimed at building understanding and acceptance of GE technology in food.

The purpose of this study was first to determine the United States adult population's level of term familiarity about genetics specifically related to plants and livestock, genetically modified organisms, genetic engineering, and the context of food. Next, we sought to determine the U.S. adult population's self-perceptions of genetic engineering through a series of questions on risk, regulation and the differences between production techniques. Finally, we determined participants' experience in agriculture and considered whether term familiarity, perceptions of GE technology, and experience in agriculture were related.

## Conceptual Framework

Understanding familiarity is an essential step to determining overall literacy about and acceptance of a particular subject for an individual or group. E.M. Rogers' (2003) Diffusion of Innovation model offers a process for adopting new information with a hierarchy of knowledge encompassing a three-step process to understanding information. The three steps to increasingly complex knowledge are *awareness knowledge*, *how-to knowledge*, and *principles knowledge*. Abrams et al. (2015) recommended that researchers using Roger's hierarchy of knowledge measure these types of knowledge independent of each other, analyzing each component on its own. In this study, we chose to assess awareness knowledge through term familiarity. Term familiarity shows understanding of a particular concept. Researching awareness through familiarity is a critical first step before researching opinion and perception. If a participant is unfamiliar with a term, they will be unable to give their informed opinion of that concept.

Term familiarity also indicates an individual's exposure to a particular item. Researchers studying a variety of contexts, stimuli, and audiences have found people prefer the familiar (Zajonc, 2001). Exposure to a specific phenomenon and frequency of exposure creates a comfort level and stronger preference as well as a higher familiarity rating. Term familiarity in the area of genetics and GE technology may relate to an individual's experience with the particular term or subject, and may influence preference for a new technology such as lab-based genetic engineering. Understanding terminology and establishing awareness is a critical first step before researchers can accurately determine consumer preferences without having to define terms in each research instrument. Therefore, we undertook this study in the context of assessing awareness knowledge and term familiarity.

## Purpose and Objectives

The purpose of this study was to understand U.S. adults' familiarity with terms related to genetic engineering for food and traditional and DNA-directed selective breeding technologies, perceptions of these technologies, and the influence of experience in agriculture on term familiarity and perceptions of these technologies in order to inform future research on consumer preferences and education on biotechnology. Specifically, our objectives were to:

1. Determine the United States adult population's level of term familiarity in the realm of genetics, specifically related to genetically modified organisms and genetic engineering in the context of food.
2. Determine the United States adult population's perceptions of GE technology for food, specifically including perceptions of health and environmental risk.
3. Assess adult public experience with agriculture.
4. Compare relationships among term familiarity, perceptions of GE technology for food and experience in agriculture.

## Methods

We surveyed a national sample of United States adults through Qualtrics, a survey software company, in August 2016. Qualtrics gathered responses through an opt-in panel of users who signed up for the company's survey pool, meaning not everyone in the population of U.S. adults had an equal probability of selection. A large sample size, however, is intended to compensate for non-probability research (Ary, Jacobs, Sorensen, & Walker, 2014). We used a gender and age quota to ensure demographic breakdown reflected the latest Census population distribution (U.S. Census Bureau, 2014) (see Table 1. Matching the U.S. census allowed us to be confident that the sample is representative of the population by gender and age. Therefore, we did not conduct explicit non-response bias testing nor use weighting based on demographics after the fact. We screened out participants using automatic checks in Qualtrics for time spent on each page of the survey as a measure of diligence. We also removed participants who typed gibberish or left blank three short-answer open-ended questions. Qualtrics offered the participants compensation for completing the 30-minute survey of which these questions were part. The [University] IRB approved this study.

Table 1

*Age, Gender and Experience in Agriculture of Respondents*

| | Gender | | | | Experience in agriculture | |
|---|---|---|---|---|---|---|
| Age | Male *n* (%) | Female *n* (%) | Other *n* (%) | Prefer not to answer *n* (%) | No Experience *n* (%) | Experience *n* (%) |
| 18-24 years | 18 (4) | 28 (7) | 5 (1) | 0 (0) | 35 (8) | 16 (4) |
| 25-44 years | 66 (15) | 76 (18) | 4 (1) | 1 (0) | 86 (20) | 61 (14) |
| 45-64 years | 75 (17) | 77 (18) | 3 (1) | 0 (0) | 107 (25) | 48 (11) |
| 65 years + | 39 (9) | 36 (8) | 0 (0) | 1 (0) | 54 (13) | 22 (5) |
| Total | 198 (46) | 217 (51) | 12 (3) | 2 (0) | 282 (66) | 147 (34) |

We determined term familiarity relating to genetic literacy using a self-report on a seven-point Likert-type scale, with labels ranging from *1- I've never heard of this,* to *4 – I know a little about this,* to *7 – I am an expert in this and can teach others.* See full set of labels in Table 2. Defining each number on the scale allowed participants to appropriately rank their familiarity and understand the meaning of each scale point. Participants responded to 17 terms, the first eight of them matching the terms asked previously in the one national peer-reviewed study we found (Abrams et al., 2015): *genetic, chromosome, susceptibility, mutation, variation, abnormality, heredity* and *sporadic*. The Abrams et al. scale did not include genetic engineering or plant- or livestock-breeding terms.

Therefore, the authors in consultation with an expert panel for construct validity, added nine additional terms specifically related to genetic engineering, genetically modified organisms, and selective breeding. Table 2 lists all the terms used for the study. The next set of questions asked the participants if they knew the difference between breeding and GE techniques, and their perceptions of the risks to health and environment for genetic engineering. Participants responded to six statements using a five-point Likert-type scale ranging from strongly disagree through strongly agree; see Table 3. Finally, to determine experience in agriculture, we asked participants to self-report aspects of their previous or current experience in agriculture. We listed several components of agriculture experience including taking classes in agriculture, having plant or animal experience, and production agriculture experience, to cover both formal and non-formal or free-choice learning experience (Stofer, 2015). See Table 4. Each of these sets of questions were in the first part of a larger survey including science literacy items, worldview items, and free-response items about definitions of GE terms. We did not examine these later literacy, worldview, and definitions items in this paper.

## Analysis

We averaged term familiarity for individual items and averaged those item scores into a total familiarity score for each participant ( "all familiarity terms"), as well as sub-scores for the terms previously studied by Abrams et al. (2015) ("Abrams terms"), and the new terms chosen for this study ("researcher-driven terms"). The Abrams terms scale had Cronbach's alpha .86, while the researcher-driven terms scale had Cronbach's alpha .98, and the combined scale of 17 terms had a Cronbach's alpha of .93, indicating acceptable reliability (Ary et al., 2014).

We grouped participants who indicated any type of experience with agriculture (see Table 4) and compared their term familiarity scores with those of participants who indicated no experience with agriculture using independent two-sample t-tests using SPSS. We also compared familiarity with terms from Abrams et al. (2015) between participant groups, as well as familiarity with just the nine terms we prepared for our survey specifically related to genetic engineering. Finally, we conducted Pearson's correlation analysis of familiarity scores averaged for the researcher-driven terms with self-perception of difference between GE technology and breeding techniques.

We calculated Cohen's d for effect size for the overall familiarity scale versus groups with or without agriculture experience using an online effect-size calculator (Becker, 1999). Cohen's d was 0.49, with an effect size of 0.24. An effect size of 0.2 is a small effect (Cohen, 1992). We used *GPower 3.1.9.2* software for Mac to compute power with this effect size. At alpha .05, our sample size gave us a power of 0.65, suggesting a 35% chance of missing an effect. Therefore we relaxed our alpha to .10, resulting in a power of 0.76 and only a 24% chance of missing an existing small effect size.

## Results

We collected a total of 429 responses for familiarity and experience and 423 total responses for questions relating to GE technology perceptions, as we eliminated six participants who did not complete the full set of GE technology perceptions questions. Our respondents' highest level of educational attainment was somewhat higher than the nation as a whole. Almost all of our participants reported earning at least a high school diploma or equivalent (99.3%), compared to census reports of attainment at this level for 88% of U.S. adults over the age of 25 in 2015. However, rates of bachelor's- (30%) and higher-degree attainment (13%) were similar to census reports.

Our first goal was to determine the United States adult population's level of term familiarity in the realm of genetics, specifically related to genetically modified organisms and genetic engineering. Out of 17 terms, heredity (7%), followed by abnormality (4%) and variation (3.5%), had the largest number of responses *I am an expert in this and can teach others* (7), where participants felt that they knew the most about those genetic-related terms. All other terms had 3% or fewer respondents indicating expert-level knowledge of the term. Only four out of the 17 terms had more than half of the population responding that they know *a fair amount* (5) and above: genetic (54.3%), mutation (52%), abnormality (57.1%) and heredity (65.3%). None of the terms the researchers added for this survey scored 5 or more with a majority of respondents. Additionally, 15% or more of the respondents scored many of the terms in the survey *I've never heard of this* (1) or *I've heard of this, but don't really know what it is* (2): susceptibility (20.7%) and sporadic (18.7%) from the Abrams terms and all of the researcher-driven terms except genetically modified organism (15.2%). Three researcher-driven terms were highly unfamiliar (scoring 1 or 2) to almost 30% of respondents: crossbred food (27.5%), hybrid organism (24.3%) and hybrid food (28%) (see Table 2). Individual terms' average familiarity scores ranged from 3.54 out of 7 for crossbred food to 5.54 for heredity. The overall average term familiarity score was 4.5, fitting right between (4) *I know a little about this* and (5) *I know a fair amount about this* (see Table 5).

The second objective was to determine the United States adult population's perceptions of GE technology for food. When it came to knowing the difference among *1) traditional selective plant or animal breeding, 2) selective breeding supplemented with DNA test information to inform breeding choices,* and *3) genetic engineering or transgenic programs*, 48% of participants agreed or strongly agreed that they did not know the difference (see Table 3). Less than half (38.3%) of participants agreed or strongly agreed that they believe that modern technologies are *not meaningfully different* and *not more risky in any important way* than traditional selective breeding. More than half (59.6%) agreed or strongly agreed that *human health is the main risk to consider* when deciding on new varieties for human consumption and there is no cause for alarm if the varieties do not cause disease in people. However, nearly two-thirds of participants (71.9%) agreed or strongly agreed that environmental impacts are important to consider not only because they could impact human health but also because the environment is important on its own.

Next we investigated participants' experience with agriculture. Nearly two-thirds of participants (66%) reported no experience in agriculture. However, the percentage of participants reporting any experience with agriculture varied with age. The middle two age groups (25-44 and 45-64) had higher levels (14% and 11%) of participants with experience in agriculture than the youngest (18-24, 4%) and oldest (65+, 5%) participants (see Table 1). The 34% of participants with experience indicated varying types of experience in agriculture, including work, classes, and other agricultural experience. Only 2% reported work in genetic engineering specifically (see Table 4).

Table 2

*Level of Familiarity with Terms Related to Genetic Engineering*

| Term | 1 – I've never heard of this | 2 – I've heard of this, but don't really know what it is | 3 – I know basically what this is but not much about it | 4 – I know a little about this | 5 – I know a fair amount about this | 6 – I know a lot about this | 7 – I am an expert in this and can teach others |
|---|---|---|---|---|---|---|---|
| | *n* (%) | *n* (%) | *n* (%) | *n* (%) | *n* (%) | *n* (%) | *n* (%) |
| Genetic | 4 (.9) | 21 (4.9) | 78 (18.2) | 93 (21.7) | 141 (32.9) | 79 (18.4) | 13 (3) |
| Chromosome | 12 (2.8) | 25 (5.8) | 75 (17.5) | 104 (24.2) | 141 (32.9) | 63 (14.7) | 9 (2.1) |
| Susceptibility | 37 (8.6) | 52 (12.1) | 73 (17.0) | 95 (22.1) | 104 (24.2) | 62 (14.5) | 6 (1.4) |
| Mutation | 5 (1.2) | 28 (6.5) | 65 (15.2) | 108 (25.2) | 138 (32.2) | 72 (16.8) | 13 (3.0) |
| Variation | 18 (4.2) | 28 (6.5) | 74 (17.2) | 107 (24.9) | 118 (27.5) | 69 (16.1) | 15 (3.5) |
| Abnormality | 8 (1.9) | 14 (3.3) | 63 (14.7) | 99 (23.1) | 136 (31.7) | 92 (21.4) | 17 (4.0) |
| Heredity | 9 (2.1) | 10 (2.3) | 50 (11.7) | 80 (18.6) | 151 (35.2) | 99 (23.1) | 30 (7.0) |
| Sporadic | 41 (9.6) | 39 (9.1) | 76 (17.7) | 96 (22.4) | 100 (23.3) | 67 (15.6) | 10 (2.3) |
| Genetically engineered organism[a] | 24 (5.6) | 51 (11.9) | 78 (18.2) | 95 (22.1) | 114 (26.6) | 59 (13.8) | 8 (1.9) |
| Genetically engineered food | 24 (5.6) | 44 (10.3) | 71 (16.6) | 103 (24.0) | 114 (26.6) | 66 (15.4) | 7 (1.6) |
| Crossbred food | 67 (15.6) | 51 (11.9) | 83 (19.3) | 99 (23.1) | 76 (17.7) | 47 (11.0) | 6 (1.4) |
| Genetically modified organism | 23 (5.4) | 42 (9.8) | 86 (20.0) | 108 (25.2) | 101 (23.5) | 61 (14.2) | 8 (1.9) |
| Genetically modified food | 20 (4.7) | 44 (10.3) | 79 (18.4) | 106 (24.7) | 115 (26.8) | 54 (12.6) | 11 (2.6) |
| Crossbred organism | 59 (13.8) | 45 (10.5) | 81 (18.9) | 101 (23.5) | 89 (20.7) | 46 (10.7) | 8 (1.9) |
| Hybrid organism | 56 (13.1) | 57 (13.3) | 79 (18.4) | 96 (22.4) | 80 (18.6) | 49 (11.4) | 11 (2.6) |
| Hybrid food | 52 (12.1) | 68 (15.9) | 73 (17.0) | 99 (23.1) | 76 (17.7) | 52 (12.1) | 9 (2.1) |
| Selective plant breeding | 54 (12.6) | 49 (11.4) | 78 (18.2) | 110 (25.6) | 47 (17.2) | 55 (12.8) | 9 (2.1) |

a. Starting with *genetically engineered organism*, terms in the lower part of the table are the researcher-driven terms

Table 3

*Participant self-report of understanding and perceptions of risk (n = 423)*

| | Strongly disagree *n*(%) | Disagree *n*(%) | Neither agree nor disagree *n*(%) | Agree *n*(%) | Strongly agree *n*(%) |
|---|---|---|---|---|---|
| I don't really know the difference among 1) traditional selective plant or animal breeding, 2) selective breeding supplemented with DNA test information to inform breeding choices, and 3) genetic engineering or transgenic programs. | 30(7.1) | 101 (23.8) | 89(20.9) | 141 (33.2) | 64(15.1) |
| I believe that traditional selective plant or animal breeding should be kept separate from the use of *any* modern technologies like DNA testing or genetic engineering/transgenics. These technologies increase the risk of ecological harm and give big companies too much control of food supplies and rural economies. | 21(5.0) | 58(13.7) | 127(30.0) | 163 (38.5) | 57(13.5) |
| I believe that the use of DNA tests to help make decisions in selective breeding programs is very different from genetic engineering programs that directly manipulate/alter DNA of plants or animals. DNA test information can make breeding programs more effective without the risks involved with genetic engineering or transgenics. | 9(2.1) | 30(7.1) | 152(35.9) | 183 (43.3) | 52(12.3) |
| I believe that all modern technologies like DNA testing within selective breeding programs or genetic engineering/transgenic programs are not meaningfully different from traditional selective plant breeding and are not more risky in any important way. We should use all tools at our disposal to try to improve the quantity and quality of plants and animals we use for food, fiber and fuel. | 33(7.8) | 81(19.1) | 150(35.5) | 128 (30.3) | 34(8.0) |
| I believe that direct harm to human health is the main risk to consider when deciding whether to allow the creation of new varieties of plants or animals for human consumption. If these new varieties don't cause diseases in people who eat them, then there is no cause for alarm. | 21(5.0) | 49(11.6) | 104(24.6) | 156 (36.9) | 96(22.7) |
| I believe that the risk of harm to ecosystems, the health of other species, and the relationships among species is important to consider when we think about creating new varieties of plants or animals; these issues are important on their own and also because of possible indirect effects on human health. | 10(2.4) | 20(4.7) | 92(21.7) | 175 (41.4) | 129 (30.5) |

Table 4

*Previous or Current Experience in Agriculture*

| Answer choice | Participants |
|---|---|
| I have no experience in agriculture | 282 (66%) |
| I have worked in food production and/or food processing | 51 (12%) |
| I have taken classes in agriculture. | 55 (13%) |
| I work/have worked in animal agriculture. | 41 (10%) |
| I work/have worked in selective breeding. | 14 (3.3%) |
| I have other agricultural experiences. | 68 (16%) |
| I feel that I am an informed consumer of agriculture. | 92 (21%) |
| I work/have worked in genetic engineering. | 10 (2%) |
| I work/have worked in plant agriculture. | 31 (7%) |

Table 5

*Term Familiarity Average Scores*

| Abrams Terms | M | SD | Researcher-driven terms | M | SD |
|---|---|---|---|---|---|
| Genetic | 5.35 | 1.86 | Genetically engineered organism | 4.01 | 1.47 |
| Chromosome | 5.28 | 2.00 | Genetically engineered food | 4.08 | 1.45 |
| Susceptibility | 4.79 | 2.31 | Crossbred food | 3.54 | 1.62 |
| Mutation | 5.44 | 1.94 | Genetically modified organism | 4.02 | 1.43 |
| Variation | 5.27 | 2.11 | Genetically modified food | 4.07 | 1.42 |
| Abnormality | 5.52 | 1.84 | Crossbred organism | 3.67 | 1.60 |
| Heredity | 5.54 | 1.71 | Hybrid organism | 3.65 | 1.63 |
| Sporadic | 4.86 | 2.31 | Hybrid food | 3.63 | 1.62 |
| | | | Selective plant breeding | 3.70 | 1.60 |

For Objective 4, we first investigated the relationship between term familiarity and agricultural experience. Averages for the overall term familiarity scale and both sub-scales were between 3.54 and 5.56 on the 1-7 scale for both experience groups. The group with agriculture experience consistently had a higher mean of familiarity than the group with no agriculture experience. Both experience groups reported less familiarity with the researcher-driven terms than the Abrams terms for both experience groups (see Table 6).

Table 6

*Familiarity Scores vs Agriculture Experience*

| Familiarity | Experience | *n* | Mean | SD | *p*-value |
|---|---|---|---|---|---|
| All Familiarity Terms | No experience | 281 | 4.28 | 1.50 | |
| All Familiarity Terms | Experience | 147 | 4.92 | 1.08 | .00 |
| Abrams Familiarity Terms | No experience | 281 | 5.10 | 1.50 | |
| Abrams Familiarity Terms | Experience | 147 | 5.56 | 1.26 | .01 |
| Researcher-Driven Terms | No experience | 281 | 3.54 | 1.39 | |
| Researcher-Driven Terms | Experience | 147 | 4.35 | 1.33 | .20 |

*Note.* Participants could select any or all choices that applied.

The difference in average scores (0.64) between participants with experience and with no experience for all of the familiarity terms was significant ($p < .01$), and the difference between groups for Abrams' terms (0.46) was also significant ($p < .01$). Lastly, the researcher driven terms had a mean difference of .80 between groups, but this difference was not significant, even at an alpha of .1 suggested by our power calculations.

We also investigated the relationship between term familiarity for the researcher-driven, GE-specific terms with self-report of understanding GE technology and breeding techniques. Overall term familiarity with researcher-driven terms was 3.84 (*SD* = 1.42, 1 to 7 scale) and self-report of GE technology understanding was 3.25 (*SD* = 1.18, 1 to 5 scale). Term familiarity and understanding of GE technology had a significant inverse relationship, with a Pearson correlation of -.49 ($p < .05$), just under the cutoff for a large effect size (Cohen, 1992).

## Discussion, Conclusions, Implications and Recommendations

We first determined whether the U.S. public truly is familiar with GE technology terms in the context of food, due to conflicting results from polls and evaluations and a lack of peer-reviewed data. The current level of term familiarity with terms related to genetic engineering among United States adults in this study is low. When participants rated their level of familiarity of 17 terms, the majority of respondents reported knowing "little" or less (4 or lower on a 1 to 7 scale) on 13 terms, including all nine of the researcher-driven terms relating to genetic engineering and plant breeding specifically. Overall, average scores of familiarity of all terms was also 4.50, with no term averaging more than 5.54, or just between knowing a fair amount and knowing a lot about the term. High percentages (15 - 30%) of participant scores of 1 or 2 for many terms indicated a high degree of unfamiliarity for these terms, especially those on the researcher-driven subscale.

Next we assessed the perceptions of participants on their understanding of GE technology and its associated risks to both human and environmental health. Half of the participants were neutral or felt they did not know the difference between GE technology, laboratory-based selective breeding, and traditional selective breeding of plants and animals. Both low levels on term familiarity and understanding of GE versus breeding technologies are consistent with or higher than earlier evaluation and research (Abrams et al., 2015; Hallman et al., 2013). However, respondents agreed that human health risks were the most important to investigate when considering items for human consumption. They also felt environmental health was important, both for its indirect impacts on human health as well as direct risks to the environment. Since we did not use unfamiliar terms, we are confident in the validity of these perceptions.

Our third aim in this study was to determine how many U.S. adults have experience with agriculture including formal secondary school experience, work experience, and other informal and nonformal experience. Self-reports of agriculture experience in our study indicated a higher estimate of people with experience, 34% of our sample, than traditional census samples reporting only those who currently work with agriculture (2%) or those who currently study agriculture in formal secondary school programs (6%). We also found differences in experience by age, with younger and older groups reporting smaller numbers of people with experience in agriculture than groups of 25-44 and 45-64 year olds.

Finally, we explored the relationships among experience with agriculture, term familiarity for GE technology in the context of food, and self-perception of GE technology understanding. First we confirmed that people with low term familiarity also reported low understanding of the differences between GE technologies and breeding techniques. A significant negative correlation for the relationship based on the wording of the questions confirmed that participants who were more familiar with specific terminology reported they understand better the difference between GE and breeding technologies. This correlation was just below the threshold (.5) for a large effect size. We also investigated experience versus term familiarity. Experience seems to play a role in familiarity with GE technology terms, though the effect sizes were small. Participants with experience in agriculture had significantly higher average scores ($p < .05$) for both all terms and the Abrams terms than participants without experience. Average scores for participants with agricultural experience on researcher-driven terms were also higher than those without experience, though the difference was not significant.

This lack of significance could be due to a lack of statistical power, as we had a 24% chance of missing a small effect at an alpha level of .10. We did have a small number ($n$ = 147) of participants with experience with agriculture. A lack of significant difference could also be a function of a problem with our researcher-driven terms scale. While reliability of the scales was above the acceptable levels, the reliability for the researcher-driven terms subscale bordered on too high (Cortina, 1993; Hulin, Cudeck, Netemeyer, Dillon, McDonald, & Bearden, 2001), suggesting a great deal of overlap or a scale that is too long overall to measure this concept. For example, we asked participants about both crossbred *organism* and crossbred *food* as well as *hybrid* organism and *crossbred* organism. Some items may need to be dropped in future research or investigated further with item-response theory.

However, the lack of significant difference between groups based on agriculture experience could also be reflective of a true lack of difference in understanding on GE technology related terms in both groups, given low overall term familiarity in participants in our study. Previous evaluations such as Hallman et al. (2013) and peer-reviewed research from Abrams et al. (2015) support this conclusion that U.S. adults are not very knowledgeable about GE technology. Surveys from Kahan (2015) indicating a lack of U.S. adult polarization on genetic engineering, coupled with related research on nanotechnology that suggest polarization on emerging technology topics might result only after participants are knowledgeable on the subjects, also support our findings of low knowledge levels in this study.

Our results indicate several areas for future research and practice. For educators, the low familiarity of genetic related terms we found, especially in the population lacking experience in agriculture, supports the mere-exposure effect for genetic engineering technology (Zajonc, 2001). Term familiarity and therefore awareness knowledge in Rogers' hierarchy is lacking among U.S.

adults on the subject of genetic engineering in the context of food. More formal, informal, and nonformal education programming on terms relating to genetic engineering will increase familiarity. Programs should also take into account dimensions of human health versus environmental risk, and they should not treat GE technology as a single issue but a series of related cases based on individual crops and their individual risks and benefit scenarios. However, given differences in familiarity based on agriculture experience, programs should look different for different audiences based on this dimension of participant background. As experience in agriculture is also low among our respondents, creating and bolstering avenues for education and exposure to more general genetic literacy as well as agriculture overall may also be helpful. Knowledge alone may not be the primary indicator of future decision-making. Therefore more overall experience in agriculture and relationships with people who support agriculture (Kahan, 2008) may increase support for agribiotechnologies.

For researchers, as participants in our study reported higher educational levels than reported by the U.S. Census and were a non-probability sample, the low scores on term familiarity assessment may actually overestimate knowledge on GE technology among the entire U.S. adult population. However, it is unclear how many participants would have learned terminology related to genetic engineering in formal school, given the recent emergence of the technology and concerns about a lack of quantity or quality agricultural or biological science education in schools. The same could be said of other demographic categories such as income. Future studies should examine the relationship of familiarity with educational background and performance in agricultural or biological sciences. Future research should also examine compare self-reports of education and other demographics with other valid and reliable scales about general science and agricultural literacy and create valid and reliable scales to directly measure knowledge of biotechnology terms and concepts. Such support will address the AAAE Research Agenda Priority 1 on agricultural literacy (Enns et al., 2016). Further, researchers might expect experience in agriculture to be more common amongst older age groups based on demographic trends about the percentages of people living and working on farms declining at the end of the 20$^{th}$ century (Environmental Protection Agency, 2013). However, we found a smaller percentage of older Americans reported any experience with agriculture, which may reflect willingness to engage with an online survey or panel. The discrepancy between census figures and our results highlights a need to have better measures of agricultural experience for many studies of these populations and topics. Future research should formalize this scale and test the items for reliability and validity. We did not examine experience with genetics more broadly, such as in medical contexts. Determining the role of experience in genetics and medical genetic engineering may also help understand support for GE technology in food. These issues may all vary in current student populations as well, and therefore these same research questions should be asked of them.

Higher familiarity can increase our confidence in studies using terms without definitions, such as those examined here. This will allow us to obtain better pictures of public perceptions and beliefs on genetic engineering for food and other crops. Future research on public support for genetic engineering should take into account that the survey population may not have the foundational knowledge necessary for discussing these complex ideas, especially without establishing definitions in the course of the research. Providing researcher-generated definitions or asking participants to generate their own definitions for comparison to other answers may be necessary to ensure meaningful, quality data. At the least, research should include assessments of term familiarity when considering such jargon-heavy technology discussions. We know Americans are not a uniform public, and the better we understand their experiences with agriculture as a potential mediating factor on acceptance of and support for genetic engineering, and more broadly, agribiotechnology, the more effectively we can target messages or interventions for particular subgroups.

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